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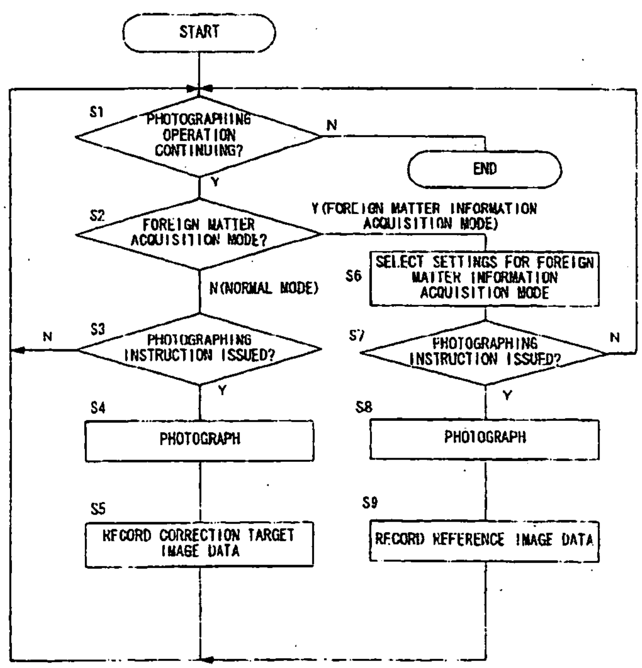
(54) Image-capturing apparatus and image processing apparatus

(57) An image-capturing apparatus, includes: an image-capturing unit that captures an image of a subject through an optical system; and a control unit that outputs images captured at the image-capturing unit as image data files, and: the control unit outputs the image data files in a format that allows an image data file containing a normal image to be distinguished from an image data file containing a reference image to be used to correct an image defect in the normal image. An image processing apparatus, includes: an input unit to which an image data file output from the image-capturing apparatus is input; an identifying unit that identifies the image data file as a file containing the reference image or a file containing the normal image; and a correction unit that corrects an image defect in the image identified as the normal image based upon the image identified as the reference image.

FIG.3



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assigned to the image data file.

[0011] According to the 8th aspect of the invention, an image processing apparatus comprises: an input unit to which an image data file output from an image-capturing apparatus according to any one of the 1st aspect through the 4th aspect of the invention is input; an identifying unit that identifies the image data file as a file containing the reference image or a file containing the normal image; and a correction unit that corrects an image defect in the image identified as the normal image based upon the image identified as the reference image.

[0012] According to the 9th aspect of the invention, it is preferred that in an image processing apparatus according to the 8th aspect of the invention 8: the image data files are each constituted of image data corresponding to pixels in the image and information related to the image; and the correction unit selects a specific reference image to be used to correct an image defect in a given normal image based upon the information related to the image contained in the image data file of the reference image and the information related to the image contained in the image data file of the normal image.

[0013] According to the 10th aspect of the invention, an image processing apparatus, comprises: an input unit to which an image data file output from an image-capturing apparatus according to any one of the 5th aspect through the 7th aspect of the invention is input; an identifying unit that identifies the image data file as a file containing the reference image or a file containing the normal image based upon the information; and an elimination unit that eliminates an effect of foreign matter present on an image-capturing optical path at the image-capturing unit from the normal image based upon the reference image.

[0014] According to the 11th aspect of the invention, a computer-readable computer program product comprises: a control program that executes a function of an image processing apparatus according to any one of the 8th aspect through the 10th aspect of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 shows the structure of an electronic camera in which interchangeable lenses are used.
FIG. 2 shows a personal computer (PC) and its peripheral devices shown together with a block diagram of the electronic camera.
FIG. 3 shows a flowchart of the processing executed in the electronic camera during a photographing operation.
FIG. 4 shows the photographing procedure executed on the electronic camera side.
FIG. 5 shows a flowchart of the processing executed at the PC when taking in image data.
FIG. 6 shows a flowchart of the processing executed at the PC to eliminate the undesirable effect of foreign matter.
FIGS. 7A and 7B show the local standardization processing executed on the brightness plane.
FIG. 8 shows a histogram of the transmittance map.
FIGS. 9A and 9B show the change in the foreign matter shadow position occurring as the pupil position changes.
FIGS. 10A and 10B show the change in the size of the foreign matter shadow occurring as the aperture value, i.e., the F value, changes.
FIG. 11 shows a table of the one-dimensional filter coefficients corresponding to the individual aperture values.
FIG. 12 shows the filter used to convert the transmittance map to a transmittance map corresponding to the aperture value F16, represented as a two-dimensional filter.
FIG. 13 shows the F value conversion executed to convert the transmittance over an area where foreign matter of medium-size is present.
FIG. 14 shows how the program is provided in a recording medium such as a CD ROM or through a data signal on the internet or the like.

DESCRIPTION OF PREFERRED EMBODIMENTS

(Structures of Electronic Camera and Personal Computer)

[0016] FIG. 1 shows the structure of a single lens reflex electronic camera (hereafter referred to as an electronic camera) in which interchangeable lenses are used. The electronic camera 1 includes a camera main body 2 and a variable optical system 3 constituted of amounted interchangeable lens. The variable optical system 3 includes a lens 4 and an aperture 5. While the lens 4 is constituted of a group of optical lenses, the figure shows a single representative lens and the position of the lens 4 is referred to as a main pupil position (hereafter simply referred to as a pupil position). The pupil position is represented by a value determined in conformance to the lens type and the zoom position of the zoom lens. The pupil position may also be affected by the focal length.

[0017] The camera main body 2 includes a shutter 6, an optical component 7 such as an optical filter or a cover

acquisition mode (a reference image acquisition mode) to photograph a reference image, which is to be detailed later, in order to obtain foreign matter information, as the photographing mode. It is to be noted that the normal mode may include a plurality of sub-modes corresponding to various types of subjects.

[0026] The image-capturing element 8 generates image signals which correspond to an optical image formed in the image-capturing area by the variable optical system 3. These image signals undergo a specific type of analog signal processing at the analog signal processing unit 12 and are then output to the A/D conversion unit 13 as analog processed image signals. The image signals having undergone the analog processing are digitized at the A/D conversion unit 13 which then provides the digitized image signals to the image processing unit 15 as image data.

[0027] It is assumed that in the electronic camera 1 achieved in the embodiment, the image-capturing element 8 is constituted of a typical single-plate color image-capturing element having R (red), G (green) and B (blue) color filters arranged in a Bayer array and that image data adopting the R G B colorimetric system are provided to the image processing unit 15. Each of the pixels constituting the image data holds color information corresponding to one of the three color components, R, G and B. While each of the photoelectric conversion elements constituting the image-capturing element 8 is referred to as a pixel in this context, each unit of the image data corresponding to a pixel is also referred to as a pixel. In addition, an explanation is given based upon the concept that an image, too, is constituted of a plurality of pixels.

[0028] The image processing unit 15 executes image processing such as interpolation, gradation conversion and edge emphasis on such image data. The image data having undergone image processing then undergo a specific type of compression processing at the compression/decompression unit 19 as necessary, and are recorded into the memory card 30 via the memory card interface unit 22.

[0029] The image data having undergone the image processing are provided to the PC 31 via the memory card 30. The image data may be provided to the PC 31 via the external interface unit 23 and a specific type of cable or a wireless transmission line. It is assumed that the image data having undergone the image processing have been interpolated with color information corresponding to all three color components R, G and B present at each pixel.

(Foreign Matter Effect Elimination Processing)

[0030] Next, the processing executed to eliminate the undesirable effects of foreign matter from individual sets of photographic image data is explained. In the embodiment, a method whereby a reference image used to obtain foreign matter information is photographed and the foreign matter effect is eliminated from a plurality of images obtained under varying optical photographing conditions by using the reference image is adopted. However, the reference image is not constituted of completely uniform or homogeneous white reference data but instead is obtained by photographing a blue sky, an almost uniform wall surface, a gray chart, a solid color paper surface or the like. The reference data used for this purpose may contain information indicating peripheral darkening of the lens, the gradation of the subject and the shading at the image-capturing element and the like. The reference data should be the type of data available under conditions in which a photographing operation can be performed easily at a readily accessible location and do not need to be completely uniform since they are converted to uniform reference data by using an algorithm on the image processing side.

(Operation Executed on the Electronic Camera Side)

[0031] Before photographing an image, the user selects either photographing mode, i. e. , the normal mode or the foreign matter information acquisition mode described earlier. The electronic camera 1 alters file information in the captured image data to be recorded into the memory card 30 in correspondence to the selected photographing mode.

[0032] FIG. 3 presents a flowchart of the processing executed in the electronic camera 1 during a photographing operation. This processing is executed when the user selects either photographing mode as described above. In step S1 in FIG. 3, a decision is made as to whether or not an instruction to continue with a photographing operation has been issued. The processing in step S1 is executed so as to allow the processing in FIG. 3 to be terminated promptly once the user issues an instruction to end the photographing operation, except for during the execution of the photographing operation or while photographic image data are being recorded. If the user has issued an instruction to continue with the photographing operation, i.e., if either of the photographing modes has been selected as described earlier, the operation proceeds to step S2. Otherwise, i.e., if the user has not selected either of the photographing modes and has issued an instruction to end the photographing operation, the processing in FIG. 3 ends.

[0033] In step S3, a decision is made as to whether or not the selected photographing mode is the foreign matter information acquisition mode. If the foreign matter information acquisitionmode is currently selected, the operation proceeds to step S6. In step S6, the photographing conditions (the aperture, the image processing details, etc.) under which a reference image is to be photographed as explained later, are set in the electronic camera 1. If the foreign matter information acquisition mode is not currently selected, i.e., if the normal mode is currently selected, the operation

image file was photographed in the foreign matter information acquisition mode and was compressed through the JPEG method. It is also to be noted that another extension may be set as long as it is different from the extension set in step S5 and that the image may be compressed through another method. The image data do not even have to be compressed.

[0041] As explained above, the electronic camera 1 varies the file extension depending upon whether the captured image data recorded into the memory card 30 were photographed in the foreign matter information acquisition mode or the normal mode (step S5, step S9). In addition, the tag information indicating the specific photographing mode in which the photographing operation was executed is attached to the corresponding photographic image data file (step S5, step S9). Thus, it becomes possible to distinguish the photographic image data recorded into the memory card 30 as either reference image data or correction target image data.

[0042] The following is an explanation of the photographing procedure which is executed to first photograph a reference image in the foreign matter information acquisition mode and then photograph a correction target image in the normal mode through the processing explained above, given in reference to FIG. 4.

1) A photographing operation 201 is executed to photograph a uniformplane with the pupil position set to P0 and the aperture value set to A0, and reference image data 0 are output.
2) A normal photographing operation 202 is executed with the pupil position set to P1 and the aperture value set to A1, and correction target image data 1 are output.
3) A normal photographing operation 203 is executed with the pupil position set to P2 and the aperture value set to A2, and correction target image data 2 are output.
4) A normal photographing operation 204 is executed with the pupil position set to P3 and the aperture value set to A3, and correction target image data 3 are output. Namely, a photographing operation of the uniform plane is executed (uniform plane photographing) by turning the electronic camera 1 toward the sky or a wall surface, and then a photographing operation is executed as desired by turning the electronic camera 1 toward a subject to be photographed (normalphotographing). It is to be noted that a correction target image that is an image photographed in the normal mode may be instead referred to as a normal image, a photographic image or a viewing image.

[0043] During this procedure, the aperture value is set to A0 so as to photograph a reference image with the aperture in the most constricted state within the range over which the aperture value can be adjusted at the variable optical system 3. The aperture value corresponding to the most constricted state may be, for instance, approximately F22 in the case of a standard lens. A correction target image, on the other hand, is photographed by setting the aperture value equal to that for the reference image or to a value further toward the open side.

[0044] The uniform plane photographing operation does not need to be executed repeatedly as long as the state of the foreign matter adhered to the optical component remains unchanged. While it is more desirable to execute the uniform plane photographing operation as often as possible, even foreign matter data obtained once a day prove useful under normal circumstances. It is up to the photographer to decide when to execute the uniform plane photographing operation. However, if a significant length of time has elapsed since the previous uniform photographing operation, the reference data obtained through the previous uniformplane photographing operation may not be reliable enough. Accordingly, the reference image data obtained through uniform plane photographing operation may be used only if the time interval between the uniform plane photographed in operation and the ensuing normal photographing operation is within a specific limit. In addition, the uniform plane photographing operation does not need to precede a normal photographing operation. Reference image data obtained through a uniform plane photographing operation executed after a normal photographing operation may be used. If a plurality of uniform plane photographing operations have been executed before and after the normal photographing operation, the reference image data obtained through the uniform plane photographing operation executed at a time closest to the normal photographing operation may be used. If, on the other hand, the user is concerned with the possibility of new foreign matter having become adhered to an optical component, reference image data selected from the two sets of reference image data corresponding to the two uniform plane photographing operations closest in time to the normal photographing operation may be used.

(Operation Executed on the Image Processing Apparatus Side)

[0045] The PC 31, which functions as the image processing apparatus, takes in the reference image data and the correction target image data described above via the memory card 30 and executes processing for eliminating the undesirable effect of the foreign matter. When taking in image data, the PC 31 distinguishes reference image data from correction target image data so as to be able to automatically select data having been identified as the reference image data to be used in the foreign matter effect elimination processing. FIG. 5 presents a flowchart of the processing executed at the PC 31 when taking into image data from the memory card 30. In step S11, one of the image files recorded in the memory card 30 is selected.

be lowered by making the most of all the available information. This also speeds up the processing since only a single plane representing the brightness component, instead of the three planes corresponding to R, G and B, needs to be analyzed. The RGB ratio for the brightness component generation does not need to be that used in the expression above, and instead, it may be set to; R:G:B: = 0.3:0.6:0.1, for instance.

2) Transmittance map generation (gain map extraction)

[0056] In step S22, a transmittance map is generated (a gain map is extracted) by executing the following processing.

2-1) Local standardization processing (gain extraction processing)

[0057] The reference image data may not be necessarily completely uniform, as explained earlier. For this reason, the brightness plane that has been generated may not be completely uniform either. A transmittance signal T[i,j] is calculated with the following expression (2) for each pixel by executing standardization (or normalization) processing to locally standardize each pixel value on such a brightness plane. Namely, the relative ratio of the value corresponding to each target pixel [i,j] and the average pixel value over a local range containing the target pixel is calculated. Through this processing, any non-uniformity attributable to the gradation, shading or the like in the uniform plane data is successfully eliminated by using an algorithm and it becomes possible to extract lowered transmittance attributable to the foreign matter shadow alone. The transmittance ascertained as described above over the entire image plane is referred to as a transmittance map (gain map). A transmittance map provides information on defects present in the reference image. It is to be noted that the term "pixel value" refers to a value indicated by a color signal (color information) corresponding to a color component or a value indicated by the brightness signal (brightness information) at each pixel. The pixel value is a value within a range of 0 - 255 when, for instance, expressed in 1 byte.

$$T[i,j] = \frac{Y[i,j]}{\left(\sum_{m=i-a}^{i+a} \sum_{n=j-b}^{j+b} Y[i+m, j+n] \right) / (2a+1)(2b+1)} \quad \ldots \quad (2)$$

[0058] The range over which the local average among (2a+1) x (2b+1) pixels is calculated should be larger than the diameter of the foreign matter. Ideally, an area that is at least 3 times as large as the foreign matter shadow should be set for the range to obtain accurate transmittance data. "a" indicates the number of pixels present to the left/right of 'the target pixel [z,j] and b indicates the number of pixels present above/below the target pixel [i,j]. For instance, if the pixel pitch at the image-capturing element 8 is 12μm and the distance between the image-capturing surface and the surface on which foreign matter is adhered is 1.5 mm, the diameter of the large foreign matter ranges over approximately 15 pixels with the aperture value set at F22 and ranges over approximately 40 pixels with the aperture value set at F4. Accordingly, "a" and "b" should each be set to 40 so as to set the local averaging range over 81 x 81 pixels. However, this is only an example and a range containing a different number of pixels may be used.

[0059] The aperture value greatly affects the seriousness of a foreign matter shadow, and while the effect of small foreign matter can be easily eliminated by opening the aperture, the effect of large foreign matter may become less noticeable but still be present over a significant area even when the aperture is adjusted to the open side. Depending upon the pixel pitch width at the image-capturing element, a round foreign matter shadow may manifest over several tens of pixels even when the aperture is adjusted toward the open side, and in such a case, the local average must be taken over a very large range to result in an increase in the length of processing time. Under such circumstances, the processing may be speeded up by calculating the local average with sub-sampled pixels.

[0060] The processing for calculating the relative ratio over the (2a+1) x (2b+1) pixel range is referred to as local standardization processing (gain extraction processing). The filter used when calculating the relative ratio over the (2a+1) x (2b+1) pixel range may instead be referred to as a gain extraction kernel. FIGS. 7A and 7B illustrate the local standardization processing executed on the brightness plane. FIG. 7A shows the brightness signals at pixels ranging along the horizontal direction within the brightness plane. Reference numerals 41 and 42 each indicate an brightness signal attenuated due to the presence of foreign matter. FIG. 7B shows the results of the local standardization processing described above executed on the brightness signals in FIG. 7A. Namely, it shows the results of standardization processing executed on pixel values within the local range. Reference numerals 43 and 44, which correspond to reference numerals 41 and 42 in FIG. 7A, each indicate the transmittance at a point at which foreign matter is present. As illustrated in FIGS. 7A and 7B, any unevenness in the gradation, shading and like contained in the uniform plane data is eliminated, and only the reduction in the transmittance attributable to the foreign matter shadow can be extracted.

noise can be substantially eliminated with accuracy. Any signal indicating a transmittance outside the + 3σ range can be considered to be an abnormal signal which can hardly be explained as attributable to a statistical error and can be assumed to represent a phenomenon induced by a lowered transmittance due to the presence of a foreign matter shadow. When an abnormality is induced by foreign matter, the abnormal signal indicates a value smaller than 1 under normal circumstances.

[0065] However, some abnormal signals may indicate values larger than 1 although such an occurrence is relatively rare. This phenomenon is not attributable to a foreign matter shadow but is attributable to, for instance, an interference fringe that manifests as a defect occurring at stria (non-uniformity in the refractive index) at an optical low pass filter or the like, increases or decreases the intensity of the incident light. Thus, the method may be adopted to detect a defect in an optical member as well as to detect foreign matter present in the optical path. In addition, the method may be adopted to determine the extent of the effect of a pixel defect manifesting within the image-capturing element. While foreign matter present close to the image-capturing element 8 tends to show clearly in a photographic image, even foreign matter on the photographic lens which becomes fairly blurred in the photographic image can be identified with a high degree of accuracy.

[0066] It is to be noted that threshold value decision-making should be executed in accordance with conditions (8), (9) and (10) below in order to eliminate the effect of foreign matter shadow alone.

$$\text{if} \quad |T[i,j]-m| \leqq 3\sigma \quad \text{then} \quad T[i,j]=1 \qquad \ldots(8)$$

$$\text{else if} \quad T[i,j]>1 \qquad T[i,j]=1 \qquad \ldots(9)$$

$$\text{else} \qquad T[i,j]=T[i,j] \qquad \ldots(10)$$

[0067] Since the average m used in the decision-making is always a value close to 1, it may be substituted by 1.

[0068] As explained above, two types of defect information, i. e. , map information representing the position of a defective pixel (judged to be defective or defect free by deciding whether or not T = 1) and transmittance information indicating the extent of the defect, are obtained at once. It is to be noted that the transmittance map, which indicates the local relative gains, may be referred to as a gain map instead.

[0069] Under normal circumstances, defects such as foreign matter are detected by using an edge detection differential filter. However, the contrast between the shadows of foreign matter present in the optical path which become optically blurred, and their surroundings is extremely low. In such a case, the differential filter, the sensitivity level of which is very low, can hardly detect any foreign matter. Instead, the statistical characteristics of the transmittance may be used in the decision-making processing as described above to detect foreign matter with an extremely high level of sensitivity, and as a result, it becomes possible to correct the undesirable effect of foreign matter present in the optical path thereby achieving the object of the present invention.

3) Pupil position conversion of the transmittance map

[0070] In step S23, the transmittance map is converted corresponding to the pupil position. The pupil position conversion is executed when the pupil position set to photograph the reference image and the pupil position set to photograph the correction target image are different from each other to convert a foreign matter position in the reference image to a foreign matter position at which the foreign matter is predicted to appear as it is viewed from the pupil position of the correction target image. FIGS. 9A and 9B show how the position of the foreign matter shadow changes as the pupil position changes. FIG. 9A shows the relationship among the pupil position, the foreign matter and the image-capturing surface of the image-capturing element 8. FIG. 9B shows how the foreign matter shadow moves on the image-capturing surface as the pupil position changes.

[0071] As FIGS. 9A and 9B clearly indicate, the position of the foreign matter appearing within the image becomes offset along the radius vector from an optical axis 51, i.e., the image center, as the pupil position changes. Bearing this in mind, an offset quantity Δr by which the foreign matter present at a position distance from the optical axis 51 within the image by r becomes offset along the radius vector is estimated. When the P0 represents the pupil position set for the reference image, P0' represents the pupil position set for the correction target image and the foreign matter is adhered at a position distanced from the image-capturing surface by 1, Δr be calculated by using expression (11) presented below.

photographed.

(Processing on the Correction Target Image)

(5) Gain correction

[0078] In step S25 in FIG. 6, a gain correction is executed by using the transmittance map obtained through the conversion processing explained above. The gain correction is executed by multiplying the R, G and B values in the correction target image data with the reciprocal of the value indicated by the transmittance signal having undergone the pupil position / F value conversion, as indicated in expressions (14), (15) and (16) respectively.

$$R[i,j] = R[i,j]/T'[i,j] \tag{14}$$

$$G[i,j] = G[i,j]/T'[i,j] \tag{15}$$

$$B[i,j] = B[i,j]/T'[i,j] \tag{16}$$

[0079] FIG. 13 shows how the transmittance is converted through the F value conversion over an area where foreign matter of medium size is present. The pixel position is indicated along the horizontal axis, and the transmittance is indicated along the vertical axis.

[0080] As described above, once a reference image is photographed with the aperture value set to the smallest value in a variable optical system, another reference image does not need to be photographed under different optical conditions Namely, by converting the foreign matter data in the single reference image, an effective correction can be achieved. As a result, the onus placed on the user of the electronic camera is greatly reduced. In addition, a very high level of sensitivity in the foreign matter detection performance can be maintained without having tophotograph a completely uniform image.

[0081] In the electronic camera 1 described above, the extension and the tag information stored in the memory card 30 together with a reference image data file are different from those stored in the memory card 30 together with a correction target image data file. Thus, when the image processing apparatus executes the processing for eliminating the foreign matter effect by taking in a data file, reference image data are automatically selected without requiring a user data file selection.

[0082] It is to be noted that data files of reference image data and correction target image data appended with extensions and tag information contents different from each other are stored in the memory card 30 and the data files are then taken into the PC 31 via the memory card 30 in the embodiment described above. Instead, such data files containing reference image data and correction target image data may be taken into the PC 31 via the external interfaces 23.

[0083] In addition, a transmittance map is generated by executing the local standardization processing and the like on a reference image of a supposedly substantially uniform plane photographed by the photographer in the embodiment. However, there may be in a small pattern or the like present in the reference image considered to be substantially uniform by the photographer. This problem can be basically solved by photographing the subject in an unfocused state. For instance, the photographer may photograph the subject by positioning it at a position closer than the shortest photographing distance of the lens. As long as the small pattern is photographed as an unfocused image that changes gently over a larger range than the range of the gain extraction kernel corresponding to (2a+1) x)2b+1) pixels, a reference image which is uniform enough to fulfill the purpose can be obtained.

[0084] while the image-capturing element in the embodiment adopts a Bayer array R, G and B colorimetric system, it goes without saying that no restrictions whatsoever are imposed with regard to the arrangement of the color filters as long as the required interpolation processing can be executed. Furthermore, the image-capturing element may adopt a different colorimetric system (such as the complementary colorimetric system).

[0085] Moreover, while an explanation is given above in reference to the embodiment on an example in which the present invention is adopted in a single lens reflex electronic still camera in which interchangeable lenses are used, the present invention is not limited to this example. The present invention may be adopted, for instance, in a camera that does not allow the use of interchangeable lenses. The pupil position and the aperture value can be ascertained by using an appropriate method in the known art.

[0086] In addition, while image data obtained by photographing images with the electronic still camera 1 are processed in the embodiment explained above, the present invention is not limited to this example. The present invention

an image-capturing unit that captures a subject image input through an optical system;
a mode switching unit that selects a first mode in which a reference image is captured by the image-capturing unit or a second mode in which a normal image is captured by the image-capturing unit;
an output unit that outputs the reference image and the normal image captured by the image-capturing unit as image data files to an external apparatus; and
an information appending unit that appends information indicating whether an image data file output by the output unit contains the reference image or the normal image to the image data file.

6. An image-capturing apparatus according to claim 5, wherein:

the information appending unit appends metadata containing information indicating either the reference image or the normal image to the image data file; and
the meta data do not alter the reference image or the normal image contained in the image data file.

7. An image-capturing apparatus according to any one of claims 5 through 6, wherein:

the information appending unit appends the information indicating whether the image data file contains the reference image or the normal image to the image data file by partially modifying a file name assigned to the image data file.

8. An image processing apparatus, comprising:

an input unit to which an image data file output from an image-capturing apparatus according to any one of claims 1 through 4 is input;
an identifying unit that identifies the image data file as a file containing the reference image or a file containing the normal image; and
a correction unit that corrects an image defect in the image identified as the normal image based upon the image identified as the reference image.

9. An image processing apparatus according to claim 8, wherein:

the image data files are each constituted of image data corresponding to pixels in the image and information related to the image; and
the correction unit selects a specific reference image to be used to correct an image defect in a given normal image based upon the information related to the image contained in the image data file of the reference image and the information related to the image contained in the image data file of the normal image.

10. An image processing apparatus, comprising:

an input unit to which an image data file output from an image-capturing apparatus according to any one of claims 5 through 7 is input;
an identifying unit that identifies the image data file as a file containing the reference image or a file containing the normal image based upon the information; and
an elimination unit that eliminates an effect of foreign matter present on an image-capturing optical path at the image-capturing unit from the normal image based upon the reference image.

11. A computer-readable computer program product comprising:

a control program that executes a function of an image processing apparatus according to any one of claims 8 through 10.

FIG.2

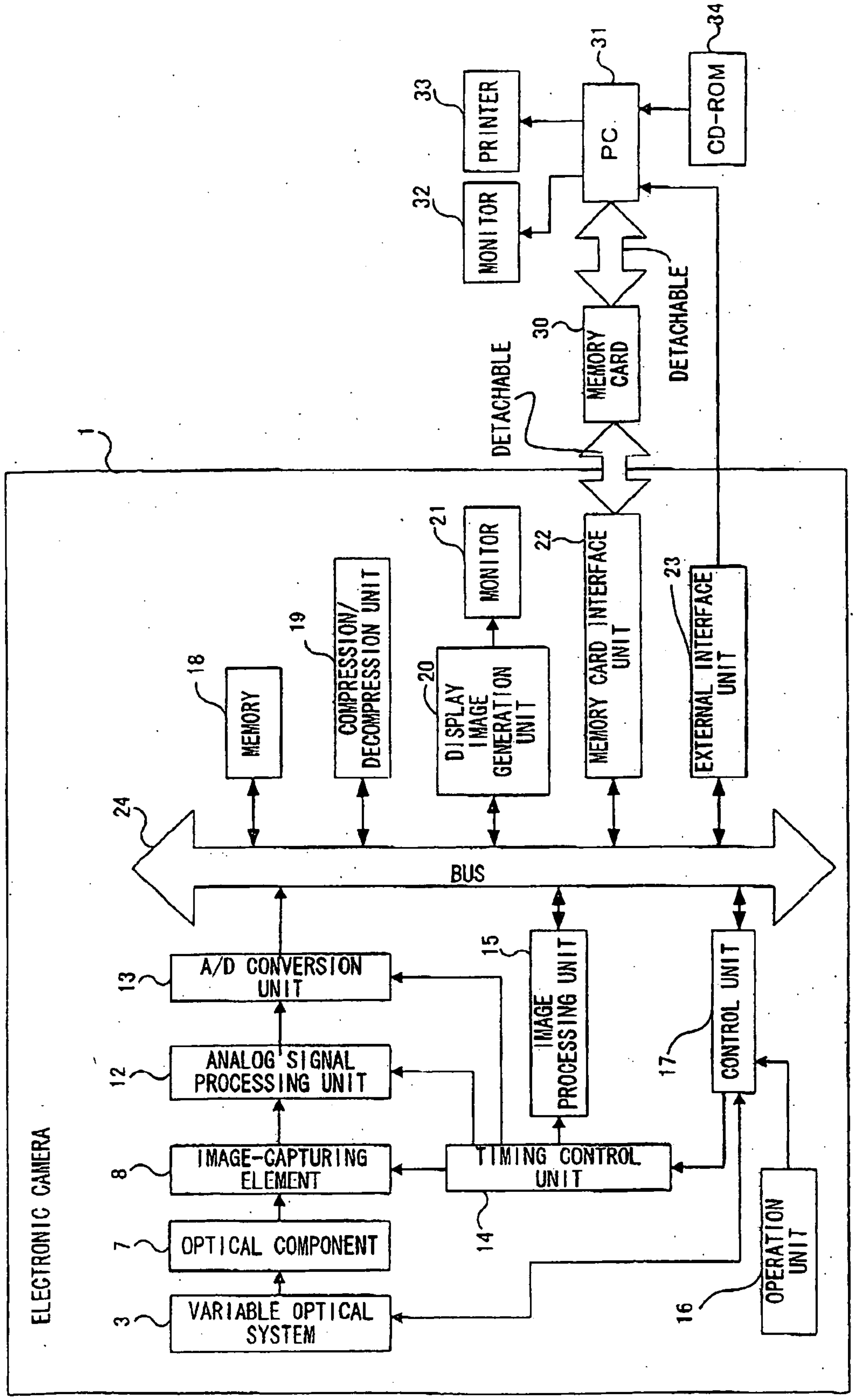

ELECTRONIC CAMERA
1
3
VARIABLE OPTICAL SYSTEM
7
OPTICAL COMPONENT
8
IMAGE-CAPTURING ELEMENT
12
ANALOG SIGNAL PROCESSING UNIT
13
A/D CONVERSION UNIT
14
TIMING CONTROL UNIT
15
IMAGE PROCESSING UNIT
16
OPERATION UNIT
17
CONTROL UNIT
24
BUS
18
MEMORY
19
COMPRESSION/DECOMPRESSION UNIT
20
DISPLAY IMAGE GENERATION UNIT
21
MONITOR
22
MEMORY CARD INTERFACE UNIT
23
EXTERNAL INTERFACE UNIT
DETACHABLE
30
MEMORY CARD
DETACHABLE
31
PC
32
MONITOR
33
PRINTER
34
CD-ROM

FIG.4

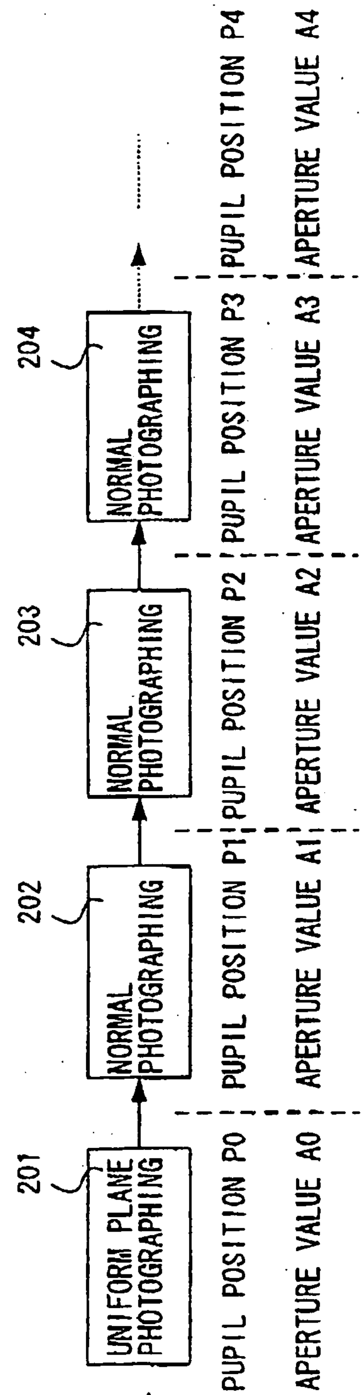
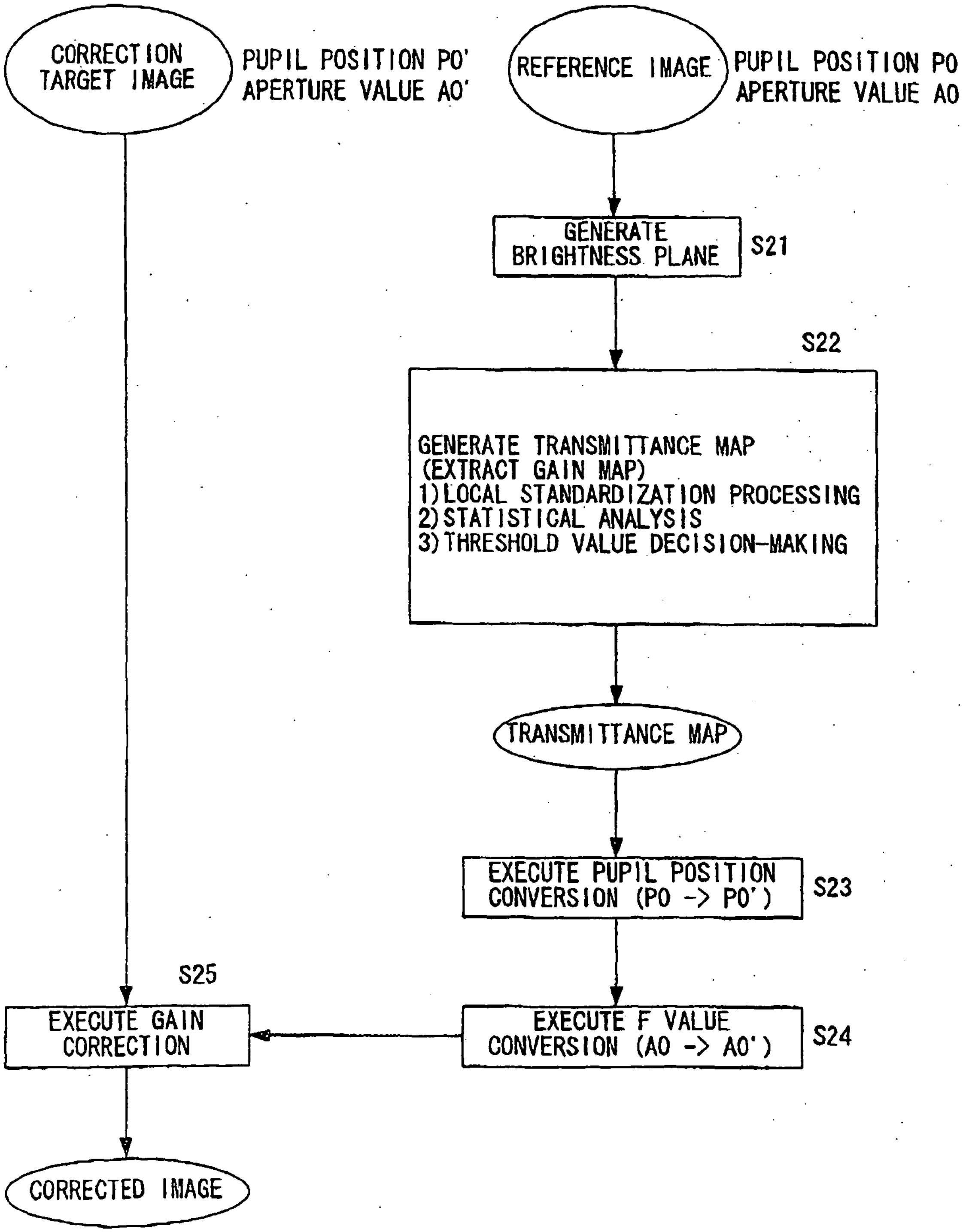

201
UNIFORM PLANE PHOTOGRAPHING
202
NORMAL PHOTOGRAPHING
203
NORMAL PHOTOGRAPHING
204
NORMAL PHOTOGRAPHING
PUPIL POSITION P0
PUPIL POSITION P1
PUPIL POSITION P2
PUPIL POSITION P3
PUPIL POSITION P4
APERTURE VALUE A0
APERTURE VALUE A1
APERTURE VALUE A2
APERTURE VALUE A3
APERTURE VALUE A4

FIG.6


CORRECTION TARGET IMAGE
PUPIL POSITION P0'
APERTURE VALUE A0'
REFERENCE IMAGE
PUPIL POSITION P0
APERTURE VALUE A0
GENERATE BRIGHTNESS PLANE
S21
S22
GENERATE TRANSMITTANCE MAP
(EXTRACT GAIN MAP)
1) LOCAL STANDARDIZATION PROCESSING
2) STATISTICAL ANALYSIS
3) THRESHOLD VALUE DECISION-MAKING
TRANSMITTANCE MAP
EXECUTE PUPIL POSITION CONVERSION (P0 -> P0')
S23
S25
EXECUTE GAIN CORRECTION
EXECUTE F VALUE CONVERSION (A0 -> A0')
S24
CORRECTED IMAGE

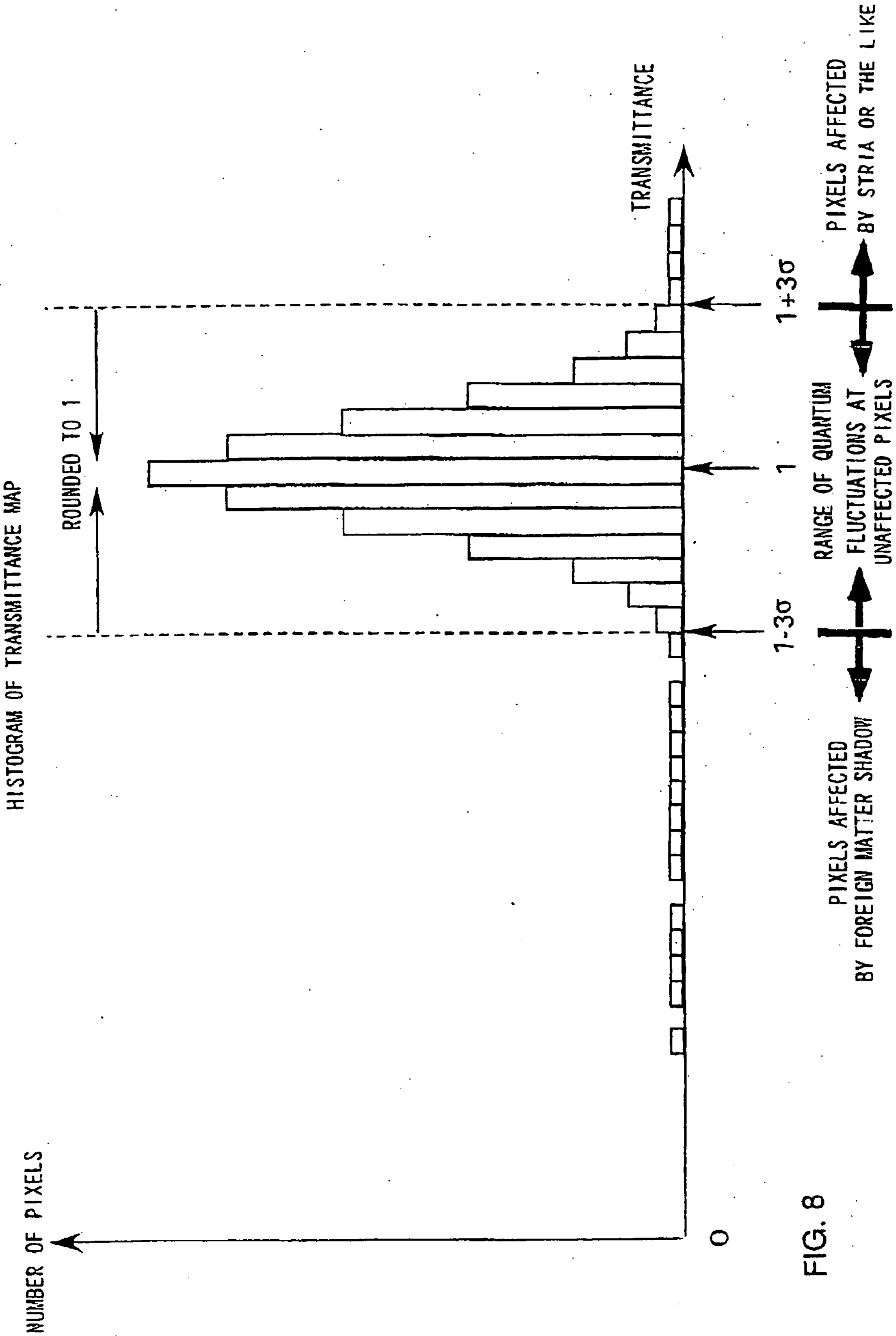

HISTOGRAM OF TRANSMITTANCE MAP
ROUNDED TO 1
NUMBER OF PIXELS
TRANSMITTANCE
0
1-3σ
1
1+3σ
PIXELS AFFECTED BY FOREIGN MATTER SHADOW
RANGE OF QUANTUM FLUCTUATIONS AT UNAFFECTED PIXELS
PIXELS AFFECTED BY STRIA OR THE LIKE

FIG. 8

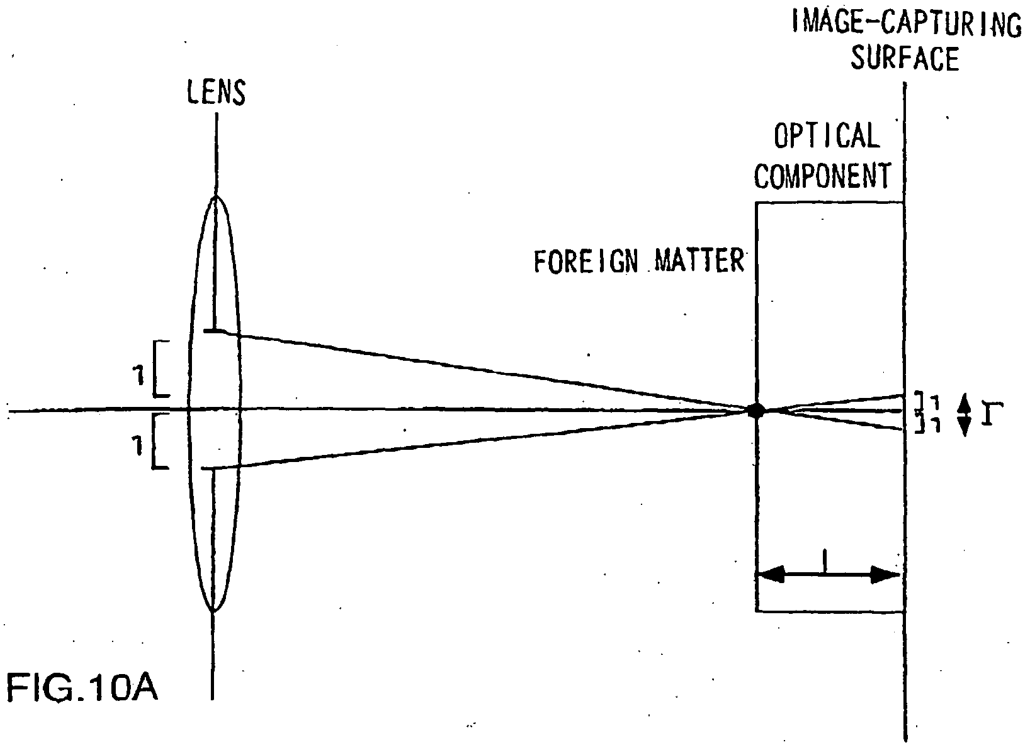


FIG.10A

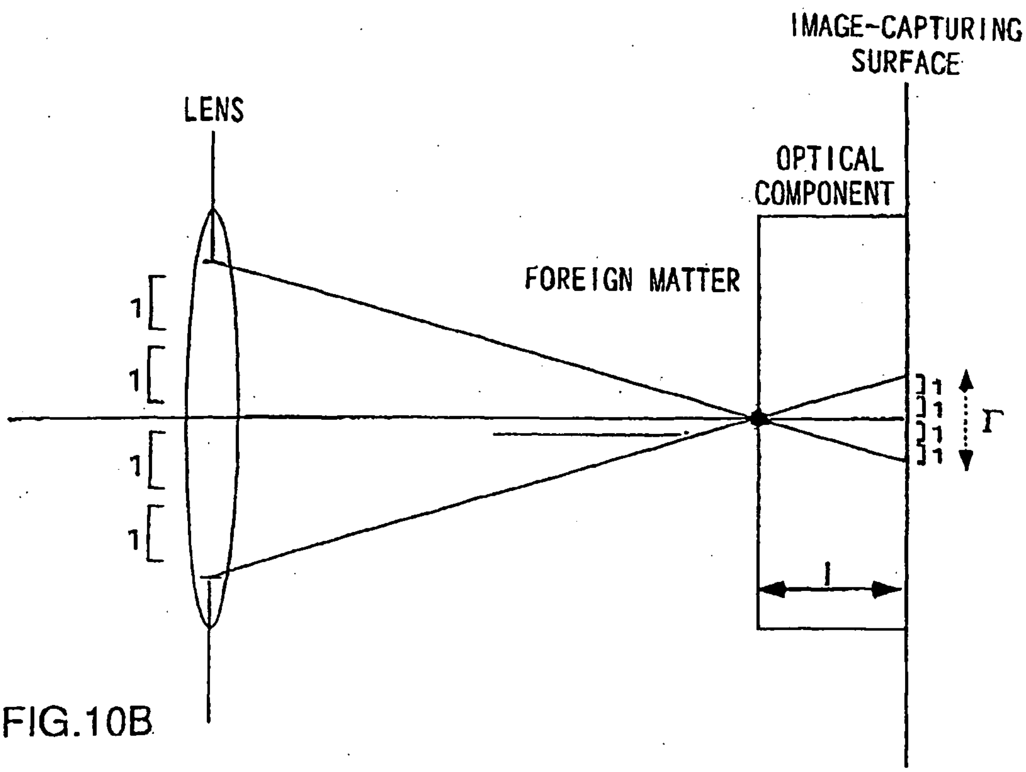


FIG.10B

FIG.12

0.25	0.5	0.5	0.5	0.5	0.5	0.25
0.5	1	1	1	1	1	0.5
0.5	1	1	1	1	1	0.5
0.5	1	1	1	1	1	0.5
0.5	1	1	1	1	1	0.5
0.5	1	1	1	1	1	0.5
0.25	0.5	0.5	0.5	0.5	0.5	0.25

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FIG.14